TITLE OF THE INVENTION

Forging method

BACKGROUND OF THE INVENTION

The present invention relates to a forging method, more specifically a forging method realized in a way to improve workability in machining, by turning the metallographical structure of products subject to impact load to a fine ferrite-perlite structure, without adopting the method of quenching and tempering, to obtain as strength a yield point (YP value) exceeding that by the method of quenching and tempering, and making the tensile strength (TS) smaller than that obtained by the method of quenching and tempering.

Conventionally, products subject to impact load such as connecting rod, steering knuckle, crankshaft, etc., for example, used to be manufactured by forging.

And, for the manufacturing of connecting rod which is momentarily subject to a large impact load, the method of quenching and tempering was also used in combination with forging, to increase its strength.

However, this method of quenching and tempering not only requires a high manufacturing cost but also is unfit for products mass-produced at low cost like automobile parts, for example, today when reduction of manufacturing cost is strongly called for and, for that reason, non-refining method capable of reducing manufacturing cost is coming to be adopted in place of the method of quenching and tempering.

This non-refining method consists in forcibly air cooling, after forging, high-temperature products at around 1200℃ immediately to around 500℃.

By the way, with the non-refining method by which high-temperature products at around 1200℃ are forcibly air cooled, after forging, immediately to around 500℃, the yield point (YP value) drops although the tensile strength (TS) remains at about the same level as with the method of quenching and tempering, and its value expressed by dividing the yield point by the tensile strength, i.e. value expressed in yield ratio (YR) is approximately 0.6. For that reason, this drop of yield point (YP value) as compared with the method of quenching and tempering puts an obstacle to reduction of weight of forged projects, while on the other hand a high tensile strength (TS) still remaining at about the same level as in the method of quenching and tempering means poor workability in machining in the same way as products manufactured by the method of quenching and tempering, and such were problems with the non-refining method.

SUMMARY OF THE INVENTION

In view of said problems with conventional forging methods, the objective of the present invention is to provide a forging method realized in such a way that it improves workability in machining by turning the metallographical structure of products subject to impact load into a fine ferrite-perlite structure, without adopting the quenching and tempering method, to obtain, as strength, a yield point (YP value) exceeding that obtained by the quenching and tempering method, and reducing the tensile strength (TS) compared to the quenching and tempering method.

To achieve said objective, the forging method according to the present invention is characterized in that a forged material manufactured by adding at least one kind of group 5 metals heated to a temperature suitable for hot forging, and after being forged to

a prescribed shape, cooled, and then held for a prescribed set time in a furnace at a tempering temperature, and is then further cooled to normal temperature by natural cooling.

Here, it is desirable to set the "tempering temperature" at a temperature in the range of 500 ~ 700℃ and the "prescribed set time" for 30 ~ 60 minutes.

In this forging method, a forged material manufactured by adding at least one kind of group 5 metals to metal material consisting of perlite, ferrite, etc. which are usually used as forged materials, is heated to a temperature suitable for hot forging and after forging to a prescribed shape, cooling, and then being held for a prescribed set time in a furnace at a tempering temperature, and is further cooled to normal temperature by natural cooling. For that reason, group 5 metals such as vanadium, niobium, etc. added to the forged material can precipitate, on ferrite, fine carbon nitride mainly comprised of added elements, and enable the setting of a high yield point (YP value) with high rigidity and strong resistance to impact load because of the fine metallographical structure of fine ferrite + perlite, making it possible to reduce the weight of forged products, control a low tensile strength (TS), and thanks to the fine metallographical structure of fine ferrite + perlite, improve workability in machining, thus promoting the reduction of manufacturing costs for forged products.

In this case, the heating temperature of the forged material shall preferably be set in the range of 1150 ~ 1250℃.

This promotes melting into a solid solution of group 5 metals such as vanadium, niobium, etc. added to the forged material, and when they are cooled and precipitated, the texture of the forged material is strained with the precipitate, and precipitates as a large volume of fine carbon nitride, while the strength of the forged

material increases because the metallographical structure becomes fine.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory drawing of the forging process showing the form of an embodiment of the forging method according to the present invention.

Fig. 2 is an explanatory drawing of temperature changes in the same forging process as above.

Fig. 3 is a graph showing the relations of hardness and yield rate between an embodiment of the present invention and conventional products (conventional non-refining method and conventional method of quenching and tempering).

Fig. 4 shows microscopic pictures of metallographical texture, (A) being a microscopic picture of the metallographical texture of the embodiment of the present invention expanded at a magnification of 400, (B) being a microscopic picture of the same expanded at a magnification of 100000, and (C) being a microscopic picture of the metallographical texture of a conventional product (conventional non-refining method) expanded at a magnification of 400, respectively.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of the forging method according to the present invention will be explained below based on drawings.

Fig. 1 and Fig. 2 indicate processes of the forging method of the present invention.

Generally, products like automobile parts, etc. momentarily subject to impact load such as connecting rod, steering knuckle, crankshaft, etc., for example, used to be manufactured by the

method of forging which is a method suitable for high strength, low cost and mass production.

The present invention, realized by improving this method, is a method in which a forged material, manufactured by adding at least one kind of group 5 metals such as vanadium, niobium, tantalum, dubnium, etc. to metal material consisting of perlite, ferrite, etc. which are usually used as forged material, is heated to a temperature suitable for hot forging and, after forging to prescribed shape, cooled, and then held for a prescribed set time in a furnace at a tempering temperature, and is further cooled to normal temperature by natural cooling.

In this case, as group 5 metals, it is preferable to use vanadium or niobium which are easy to obtain and inexpensive, though not restricted to those items.

And, the added volume may be very small at about 0.03 to 0.3 wt% against the forged material, for example.

When performing hot forging by using this forged material, the heating temperature shall be set slightly lower than the heating temperature suitable for conventional hot forging (this heating temperature varies also depending on the type of forged material) or at about 1200℃ ± 50℃, in the case where the heating temperature suitable for conventional hot forging is around 1250℃, for example.

By setting the heating temperature of forged material as described above, it becomes possible to promote melting into solid solution of group 5 metals such as vanadium, niobium, etc. added to the forged material and, when they are cooled and precipitate, the texture of the forged material is strained with the precipitate and precipitates as a large volume of fine carbon nitride, increasing the strength of the forged material.

And, this forged material heated to a temperature suitable for hot forging is molded to prescribed shape by hot forging using dies.

This hot forging process is the same as that in the conventional non-refining method and method of quenching and tempering.

After the forging, the forged product released from the die is cooled, by natural cooling, to a temperature close to the temperature at which group 5 metals such as vanadium, niobium, etc. can easily precipitate, on the ferrite, fine carbon nitride mainly composed of added elements. This cooling temperature, which is not particularly restricted, will be set for approximately 600 to 800℃.

This natural cooling may be made naturally during conveyance on the conveyor where the forged products discharged from the forging system are carried continuously to the heating furnace of the subsequent process, or made forcibly by such means as blowing air with a blower to the forged products on the conveyor, etc. These methods can be adopted selectively as required, depending on the carrying distance from forging system to heating furnace, required carrying time, etc.

In this way, forged products cooled to approximately 600 to 800℃ are supplied into the heating furnace.

It is so arranged that, in this heating furnace, the forged products can maintain a temperature in the tempering temperature area or 500 to 700℃, for example.

In this case, since the thermal energy of the forged products supplied into the heating furnace is set slightly higher than the temperature in the heating furnace, the set temperature is maintained in the heating furnace without hardly any heating except in the early period of operation, enabling energy-saving

treatment (of the forged products).

The holding time of this tempering temperature will be set for a time necessary for the group 5 metals such as vanadium, niobium, etc. to precipitate, on the ferrite, fine carbon nitride mainly composed of added elements, or 30 to 60 minutes or so, for example.

In that case, use of heating furnace is not always necessary, if it is possible to maintain the prescribed temperature during the time necessary for precipitating, on the ferrite, fine carbon nitride mainly composed of added elements, by using an oven such as heat insulating oven, etc.

As described above, after the forged products are maintained at 500℃ to 700℃ in the heating furnace for approximately 30 to 60 minutes, to make the group 5 metals such as vanadium, niobium, etc. precipitate, on the ferrite, as fine carbon nitride mainly composed of added elements, the forged products are taken out from the heating furnace, and cooled to normal temperature by natural cooling, into products.

This makes it possible to realize a fine metallographical structure close to that obtained by normalizing and set a high yield point (YP value) for high rigidity and strong resistance to impact load, and to thus sharply improve the yield ratio (YR). As a result, reduction of weight can be achieved and yet the tensile strength (TS) can be controlled low, enabling to obtain forged products with improved workability in machining.

Table 1 and Table 2 indicate differences between the non-heat treated carbon steel for machine structure (S35C) to which are added 0.26% vanadium and 0.026% niobium of an embodiment of the forging method according to the present invention and conventional products (products by conventional non-refining

method and conventional method of quenching and tempering (carbon steel for machine structure with equivalent carbon content (S40) (Table 2 (A)) and with equivalent strength value (S55C) (Table 2 (B)))).

【Table 1】

<table>
<tr><th>Item</th><th>Present invention</th><th>Non-refining method</th></tr>
<tr><td>Heating temperature for forging</td><td>1220 ℃</td><td rowspan="4">1220 ℃
Blast cooling
(to 500 ℃),
and air cooling after that</td></tr>
<tr><td>Supply temperature for heating furnace after natural cooling</td><td>800 ℃</td></tr>
<tr><td>Set temperature in heating furnace</td><td>600 ℃</td></tr>
<tr><td>Set temperature holding time</td><td>30 minutes</td></tr>
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【Table 2】

Item	Present invention	Non-refining method	Method of quenching and tempering (A)	Method of quenching and tempering (B)
Tensile strength (N/mm^2)	1140	1162	782	962
Yield point (N/mm^2)	892	733	585	710
Yield ratio (YR)	0.78	0.63	0.75	0.74
Elongation	11.6	13.7	23.8	20.0
Reduction of area	19.2	19.6	63.8	54.4
Texture	Ferrite + Perlite	Ferrite + Bainite	Sorbite	Sorbite + Ferrite
Treating method	As described in the Specification	Same as left	842 ℃ Water cooling 538 ℃ Tempering	Same as left
Remarks	V 0.26% Nb 0.026% Non-heat treated steel	Same as left	S40C	S55C

For said method of quenching and tempering, data were borrowed from ASME Hand Book (1954).

Fig. 3 indicates the relations of hardness and yield rate between an embodiment of the present invention and a conventional product (conventional non-refining method and conventional method of quenching and tempering).

Fig. 4 shows microscopic pictures of metallographical texture.

Fig. 4 (A) is a microscopic picture of the metallographical texture of the embodiment of the present invention expanded at a magnification of 400, Fig. 4 (B) is a microscopic picture of the same expanded at a magnification of 100000, and Fig. 4 (C) is a microscopic picture of the metallographical texture of a conventional product (conventional non-refining method) expanded at a magnification of 400, respectively.

From those microscopic pictures, we can see that the metallographical texture of an embodiment of the present invention is a fine texture.

Moreover, as it is apparent also from the microscopic picture expanded at a magnification of 100000 indicated in Fig. 4 (B), fine carbon nitride mainly composed of added elements is precipitated on the ferrite, showing improved strength of the forged material.